REMOTE SENSING BY ERTS SATELLITE OF VEGETATIONAL RESOURCES BELIEVED TO BE UNDER POSSIBLE THREAT OF ENVIRONMENTAL STRESS

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Work carried out under a grant by

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to Bethune-Cookman College

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ABSTRACT

The distribution of natural vegetation types which are possibly under some threat of environmental stress, on North Merritt Island, Florida, was studied by analysis of ERTS Satellite Multispectral Scanner data on the Image-100 Computer System. The boundaries of six distinct plant associations were located on photos made on the Image Analyser, with a non-significant mean error of -24.38 meters. The six plant associations are described as I. Aquatic Estuarine Association, II. Mangrove, III. Spartina swamp, IV. Wooded swamp, V. Sabal Hammock, VI. Oak-palmetto, each having a characteristic spectral signature. The difference in average reflectance "grey level" between the lowest of the four spectral scanning bands (Channel 1 of Image-100) and the highest spectral scanning band (Channel 4) for the six vegetation types were I. +8.30, II. +4.50, III. +0.42, IV. --1.97, V. -6.22, VI. --12.53. The decreasing trend of the differences is strongly negatively correlated with height of land, the coefficient of correlation being -.9696.

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INTRODUCTION

Under an Educational Grant made by the National Aeronautics and Space Administration, Bethune-Cookman College is conducting a program for the study of the environment in the neighborhood of the John F. Kennedy Space Center which includes remote sensing of plant communities with a view to observing possible deterioration which may result from extensive mechanical ground operations and in due course, exhaust fumes from space vehicles. The present paper deals only with the aspect of remote sensing of the plant associations in the North Merritt Island area of the Kennedy Space Center with the purpose of developing a technique for the measurement of vegetational resources in general, resources which constitute a continuous primary storage system for solar energy and which is at the same time subject to deterioration under conditions of intensive utilization of other forms of energy in its immediate neighborhood.

MATERIALS AND METHODS

The present study was based upon the vegetation types of North Merritt Island which is shown as the diagonally shaded area on Figure 1. Because of the present intensive construction program which is in progress in the area and because of the large volumes of exhaust gases of space vehicles which are expected to influence the area in the future, the plant associations will be studied over an adequate period of time to observe possible changes. One of the more important methods of study will be remote sensing. In the first stage of such a study, data acquired by the four-channel Multispectral Scanner of the ERTS Satellite (1) was analysed on the Image-100 Interactive Multispectral Image Analysis System.

The Multispectral Scanner of the ERTS Satellite is a four-band scanner which operates in the solar-reflected spectral band region between 0.5 and 1.1 micrometer wavelengths. The earth's surface is scanned in the four spectral bands simultaneously at an orbital velocity which permits a global coverage every 18 days. The four bands are: -

Band 1	0.5 - 0.6 micrometers
Band 2	0.6 - 0.7 micrometers
Band 3	0.7 - 0.8 micrometers
Band 4	0.8 - 1.1 micrometers

The data received by the ERTS scanner are reformatted and written on magnetic tape by the Ground Data Handling System at Greenbelt, Maryland. It is finally transmitted to the NASA Data Processing Facility for cataloging and dissemination to users.

The IMAGE-100 is an Interactive Multispectral Image Analysis System which is capable of extracting information from multispectral imagery data loaded from magnetic tape. Thematic images extending over parts of the ERTS scene under study, may be developed and stored temporarily to be used for the creation of composite thematic imagery of contrasting colors representing the different types of vegetation which occur in the area. The imagery is shown on the primary display device, a color CRT, and it may be photographed for further study. Next to the Image Analyser Console is a Graphics Display Terminal which shows the spectral signature of each theme in the form of four frequency histograms which refer to that part of the scene enclosed within the training area selected by the operator with the use of a moveable cursor. The four histograms give for each of the four multispectral channels, characteristic reflectance grey levels on the horizontal axis and number of picture elements associated with the grey levels, on the vertical axis. A printed output of the Graphic Display is also available

giving among other data, the spectral boundaries, means and variances of each of the four channels. Thus it is possible to obtain by use of the Image-100 System, color themes representing vegetation types and spectral characteristics for each theme.

The ERTS data on which image analysis was carried out for the purposes of this paper were acquired on 18th March, 1974. In the process of image analysis on the Image-100 System it was found in this project that the themes and spectral signatures produced by single pixel training and 36 pixel training on the ERTS scene, were not appreciably different from each other. The cursor was used for systematic exploration of the ERTS scene until a set of more or less mutually exclusive themes were developed which occupied the total surface. Each theme was photographed with High Speed Ektachrome film having a sensitivity of ASA 160. A printed output of the spectral characteristics of each theme was also obtained.

Although there was a certain amount of prior knowledge of the distribution of vegetation types on North Merritt Island, it was nevertheless necessary to carry out extensive field studies in order to determine the degree of correlation which may exist between color themes and distribution of plant associations in the field.

In order to compare theme distribution with the distribution of vegetation, measurements were made from the point X to the point Y shown on Figure 1 both across the themes shown on Figure 3 and across the corresponding strips of vegetation in the field. The widths of theme strips were converted to field scale and the differences between the derived values and corresponding vegetation strips were used for computing a mean difference and its standard error (3).

Based upon the observation that the height of the land above water level or the water table increases from the point X on Figure 1 towards the center of the Island, that vegetation types change as one moves Eastward from X and that the spectral characteristics of the themes appear to alter systematically with changes in theme from X toward Y, a correlation study was carried out between mean height of land (X) for each vegetation type and difference between average grey level of channel 1 and channel 4 (Y) for each vegetation type.

RESULTS

Multispectral data received from the NASA Data Processing Facility for North Merritt Island on ERTS tape for 18th March, 1974, were analysed on the Image-100 Interactive Multispectral Image Analysis System for comparison of imagery themes with plant associations which they may represent.

In examining the correspondence between imagery produced on the Image-100 from ERTS multispectral data and vegetation types three related approaches were adopted. In the first instance the general distribution of the individual imagery themes on the ERTS scene were compared with the distribution of corresponding vegetation types in the field. In a more precise study, widths of theme strips measured along the line X Y shown in Figure 1, coverted to field scale, were compared with actual field widths of corresponding vegetation types. The third approach in comparing image and field features consisted of correlating height of land of the vegetation types with their spectral characteristics.

Comparison of color themes with vegetation types.

In developing the color themes on the ERTS scene representing North Merritt Island and shown as the diagonally shaded area in Figure 1, one pixel and 36 pixel size cursors were used systematically across the scene until a number of more or less mutually exclusive themes were produced. A composite of the six themes thus produced is shown in Figure 3. The composites produced with one pixel and 36 pixels are not appreciably different. An examination of the colors on Figure 3 along the line X Y shown in Figure 1, starting at X and proceeding East shows that the following colors occur in order: - I. Light blue, II. Red, III. Brown (theme not developed), IV. White, V. Yellow, VI. Purple. The colors I to VI may be written in that order to represent the vegetation types I to VI in Table 1. Ground truthing expeditions indicated that the vegetation type corresponding to each color theme is consistently confined to its own theme.

Correspondence between theme borders and actual plant association borders.

A more precise correlation of imagery color themes and distribution of vegetation in the field was carried out by comparing widths of theme strips on Figure 3 measured along the line X Y of Figure 1, with the widths of corresponding vegetation strips in the field. The differences between the widths of theme strips converted to field scale and the widths of vegetation strips, were utilized for calculating the mean difference and its standard error. Nine such strips were studied along the line X Y of Figure 1 and the nine corresponding differences are shown in Table 2. The mean difference between actual widths of vegetation strips and widths as estimated from ERTS imagery is shown at the bottom of Table 2 to be $\pm$4.38 meters. This value is not significantly different from zero, on a probability of P = .05.

Correlation between height of land and spectral features of vegetation types.

A third method of studying the correspondence between ERTS multispectral data and plant associations consisted of examination of the degree of correlation between height of land of each association with spectral features of the association. Figure 2 gives relative widths of color theme strips along the line X Y shown in Figure 1. The numbers I to VI shown on Figure 2 refer to the vegetation types of Table 1 and to the colors light blue, red, brown, white, yellow and purple respectively, one color corresponding with one vegetation type. Figure 2 shows that the six vegetation types correspond with six characteristic land levels, the height of the land increasing from the point X towards the East. Because an examination of the multispectral data of the six vegetation types showed that there was a systematic change in the spectral features from low lying land to higher land, the degree of correlation between spectral signatures and height of land was determined. The feature of the spectral characteristics which appeared to be the best correlated with height of land was the difference between the average grey levels of Channels 1 and 4 of the Image-100 output. The pairs of values recorded for height of land (X) and differences in grey levels of Channels 1 and 4 (Y) are given in Table 3. The correlation coefficient between the factors X and Y is shown at the bottom of the table to be -.9696 which is a large negative and significant value with a standard error of .3134. (4)

CONCLUSIONS

1. Data acquired by ERTS Satellite Multispectral Scanner was processed on the IMAGE-100 Interactive Multispectral Image Analysis System to identify and define the distribution of six principal plant associations on North Merritt Island, Florida.

2. The borders of the six plant associations were located with a mean error of -24.38 meters, a value which is not significantly different from zero on a probability of P = .05.

3. The spectral signatures of the six plant associations are systematically related to each other as reflected in the very high negative and significant correlation coefficient of -.9696 between the height of land of the association on the one hand and the difference in reflectance grey level between Channels 1 and 4 of the IMAGE-100 output.

TABLE 1

Principal plant associations of North Merritt Island
and their more dominant species

I. Aquatic Estuarine Association

Thalassia testudinum. Turtle grass.
Spartina alternifolia. Cord grass.
Zostera marina.
Ulva lactuca.
Gracilaria confervoides.
Acetabularia crenulata.

II. Mangrove Association

Laguncularia racemosa. White mangrove.
Avicennia nitida. Black mangrove.
Baccharis halimifolia. Groundsel.
Schinus terebinthifolius. Brazilian pepper.
Borrichia frutescens. Seaside ox-eye.

III. Spartina-Typha Swamp

Spartina bakerii. Bunch grass.
Juncus roemerianus. Black rush.
Typha angustifolia. Cat tail.
Acrostichum danaeaefolium. Leather fern.

IV. Swampy woodland

Salix caroliniana. Willow.
Baccharis halimifolia. Groundsel.
Typha angustifolia. Cat tail.
Ilex glabra. Gallberry.
Sabal palmetto. Sabal.
Myrica cerifera. Wax myrtle.

V. Sabal - Quercus - Acer - Magnolia hammock

Sabal palmetto. Sabal palm.
Quercus virginiana. Seaside live oak.
Acer rubrum. Red maple.
Salix caroliniana. Willow.
Magnolia virginiana. Swamp magnolia.

VI. Oak-Palmetto Association

Quercus sp. Scrub oak.
Serenoa repens. Palmetto.
Smilax auriculata. Green briar.
Vitis rotundifolia. Wild grapes.

TABLE 2

Estimate of standard error of widths of vegetation strips as measured on Image-100 picture produced from ERTS tapes

Differences between actual width and width obtained from the picture (meters)
+ 4.39
+ 8.78
- 57.06
- 118.51
- 8.78
- 21.95
- 26.33
- 21.95
+ 21.95
- 219.46

Mean difference = -24.38 meters

Std. Error of mean diff. = $\pm$ 14.07

Significant difference (P = .05, n = 8) must exceed $\pm$ 32.45.

TABLE 3

Correlation between height of land above water level or water table in meters (x) and difference in average grey levels* of Channels 1 and 4

Plant Association	Height of land in meters (x)	Mean grey level* Channel 1	Channel 4	Channel - Channel 4 (y)
I. Aquatic flora	-1.22	9.33	1.03	+8.30
II. Mangrove	- .61	12.00	7.50	+4.50
III. Spartina swamp	- .30	13.03	12.61	+0.42
IV. Swampy woodland	- .23	10.47	12.44	-1.97
V. Sabal hammock	- .08	12.06	18.28	-6.22
VI. Oak-palmetto	+ .91	10.50	23.03	-12.53

*Grey levels refer to operator selected density levels of reflectance which quantize the multispectral data into discrete ranges.

Correlation coefficient (r_{xy}) = -.9696

Standard error of r_{xy} = .3133

Figure 1

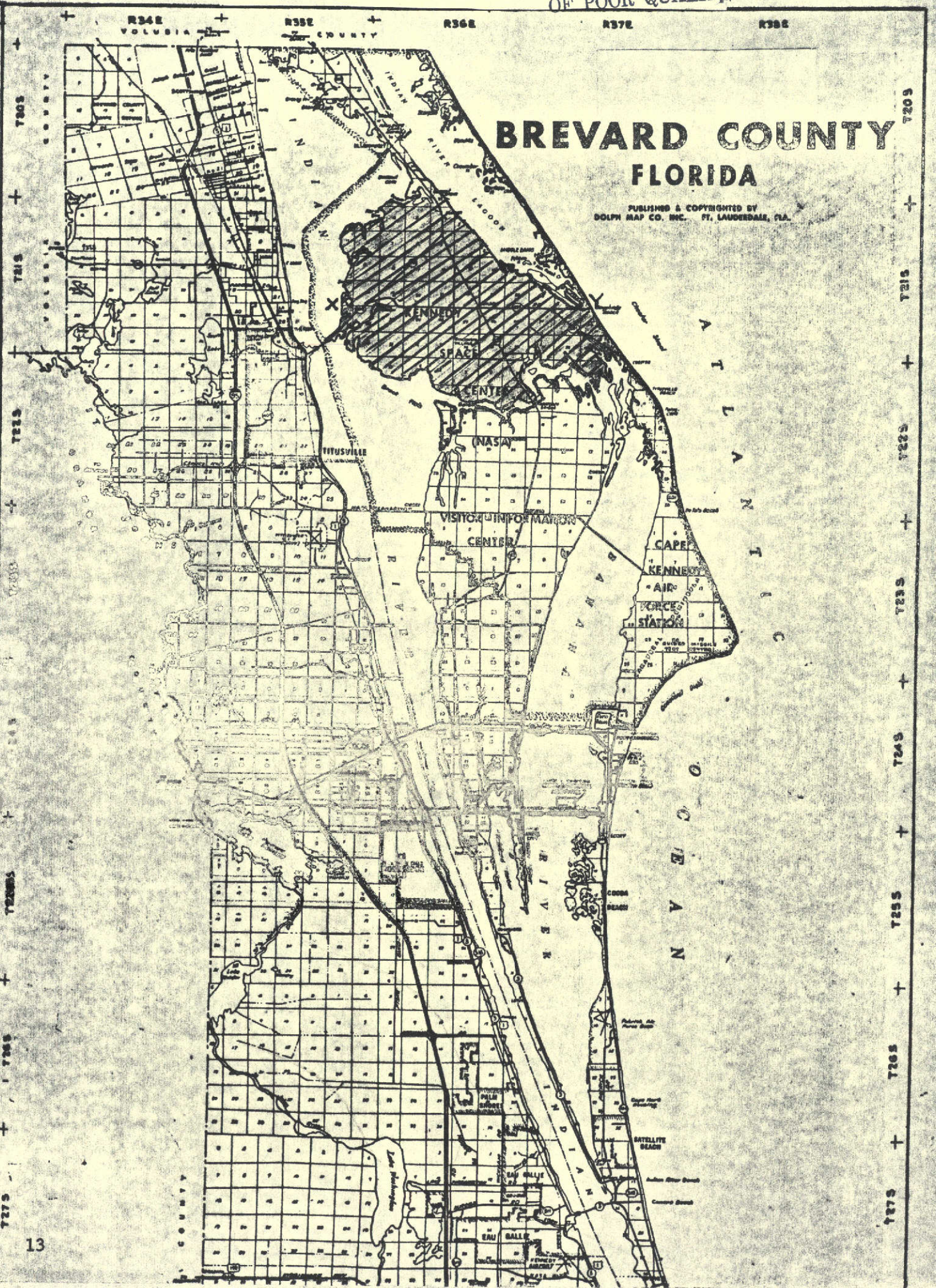
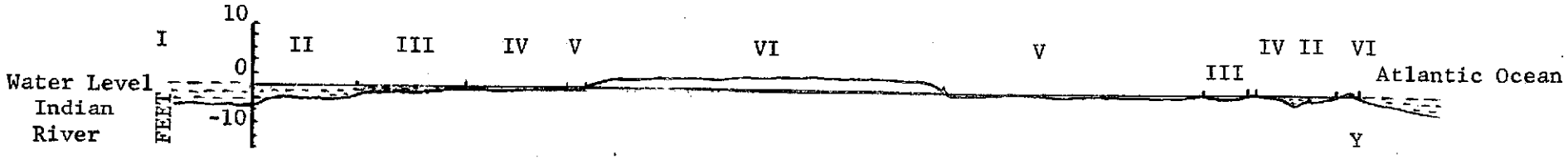


FIGURE 2

Relative widths of vegetation types which occur along a line near and parallel to State Road 402, Brevard County, Florida.



Legend:

I. Aquatic Estuarine Association.

II. Mangrove Association.

III. Spartina Typha Swamp.

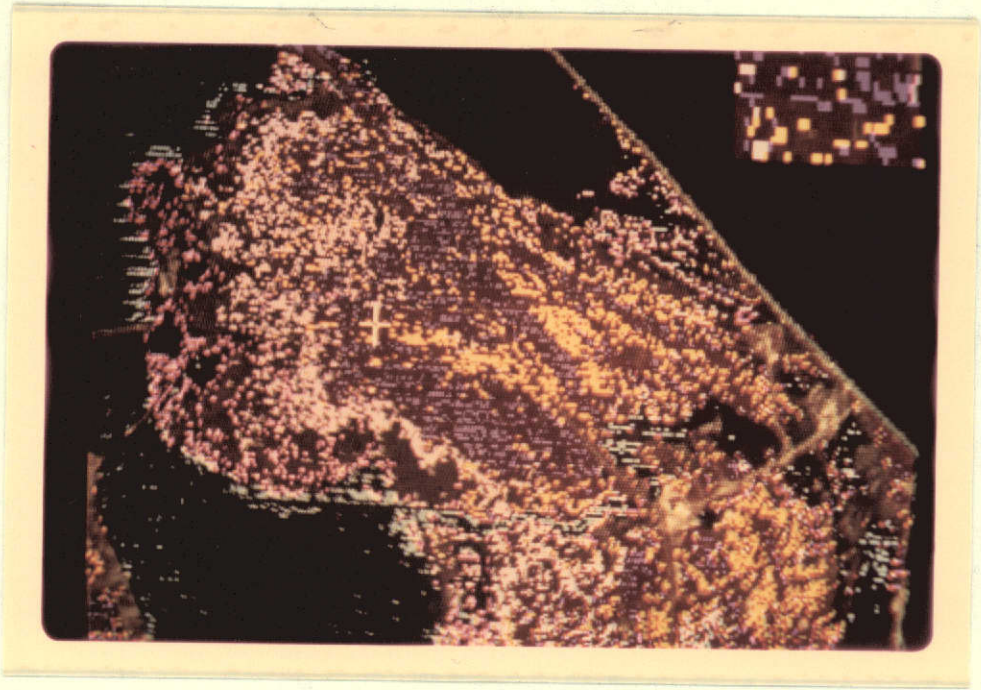
IV. Swampy woodland.

V. Sabal - Oak - Red maple - Magnolia hammock.

VI. Oak - Palmetto Association.

FIGURE 3

Color themes produced by IMAGE-100 representing 6 plant associations



I. Blue = Aquatic Estuarine Association
II. Red = Mangrove
III. Brown = Spartina swamp
IV. White = Wooded swamp
V. Yellow = Sabal - Acer Hammock
VI. Purple = Oak-palmetto

PHOTO I. Aquatic Estuarine Association

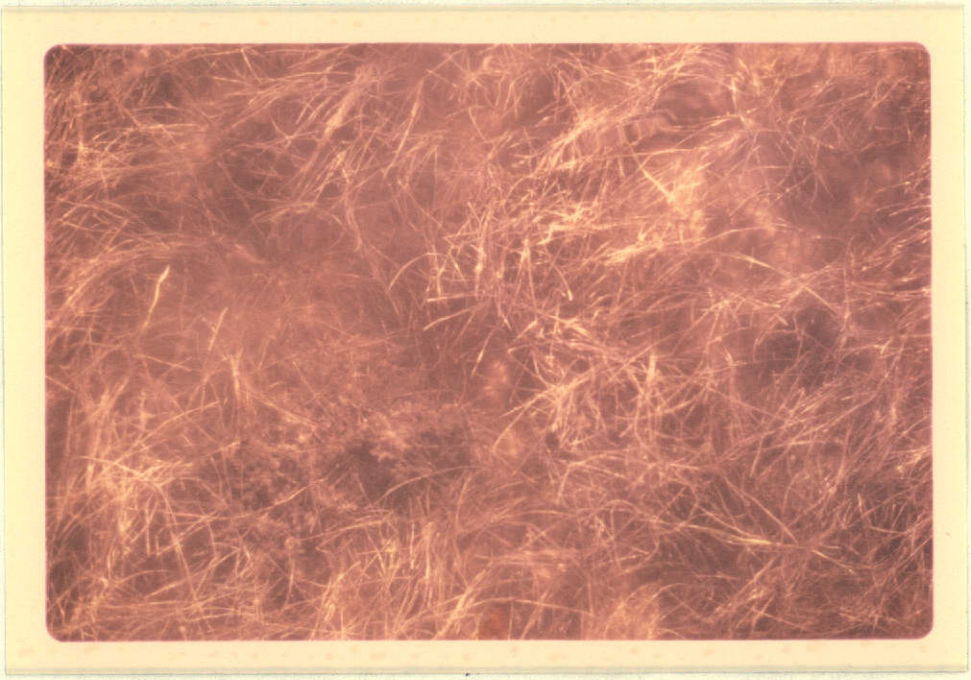


PHOTO II. Mangrove Association

PHOTO III. Spartina-Typha Swamp

PHOTO IV. Wooded Swamp

PHOTO V. Sabal - Acer Hammock

PHOTO VI. Oak-Palmetto Association

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